Thinking Recursively

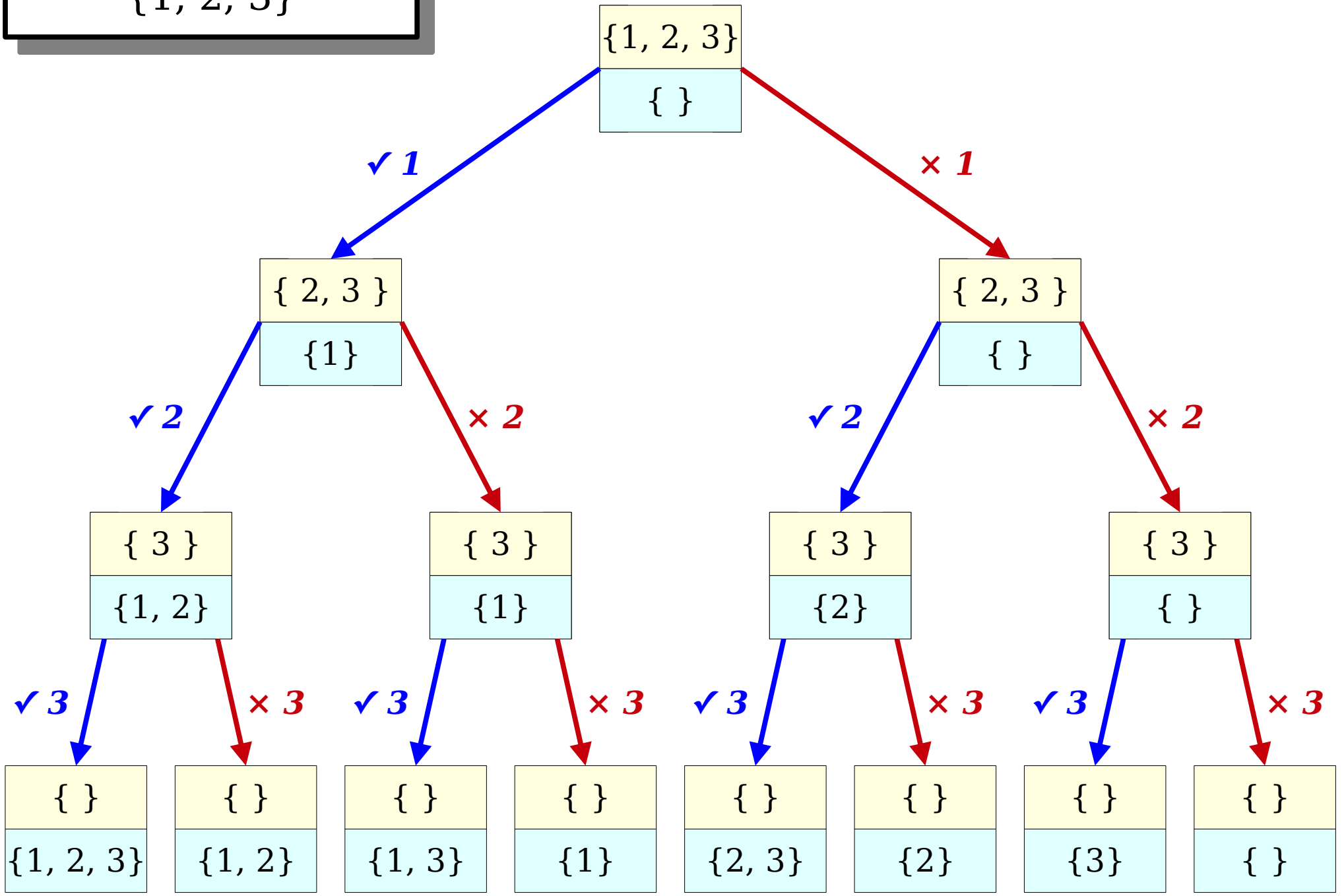
Part III

Outline for Today

- ***Iteration + Recursion***
  - Combining two techniques together.
- ***Enumerating Permutations***
  - What order should we do things?
- ***Enumeration, Generally***
  - How to think about enumeration problems.

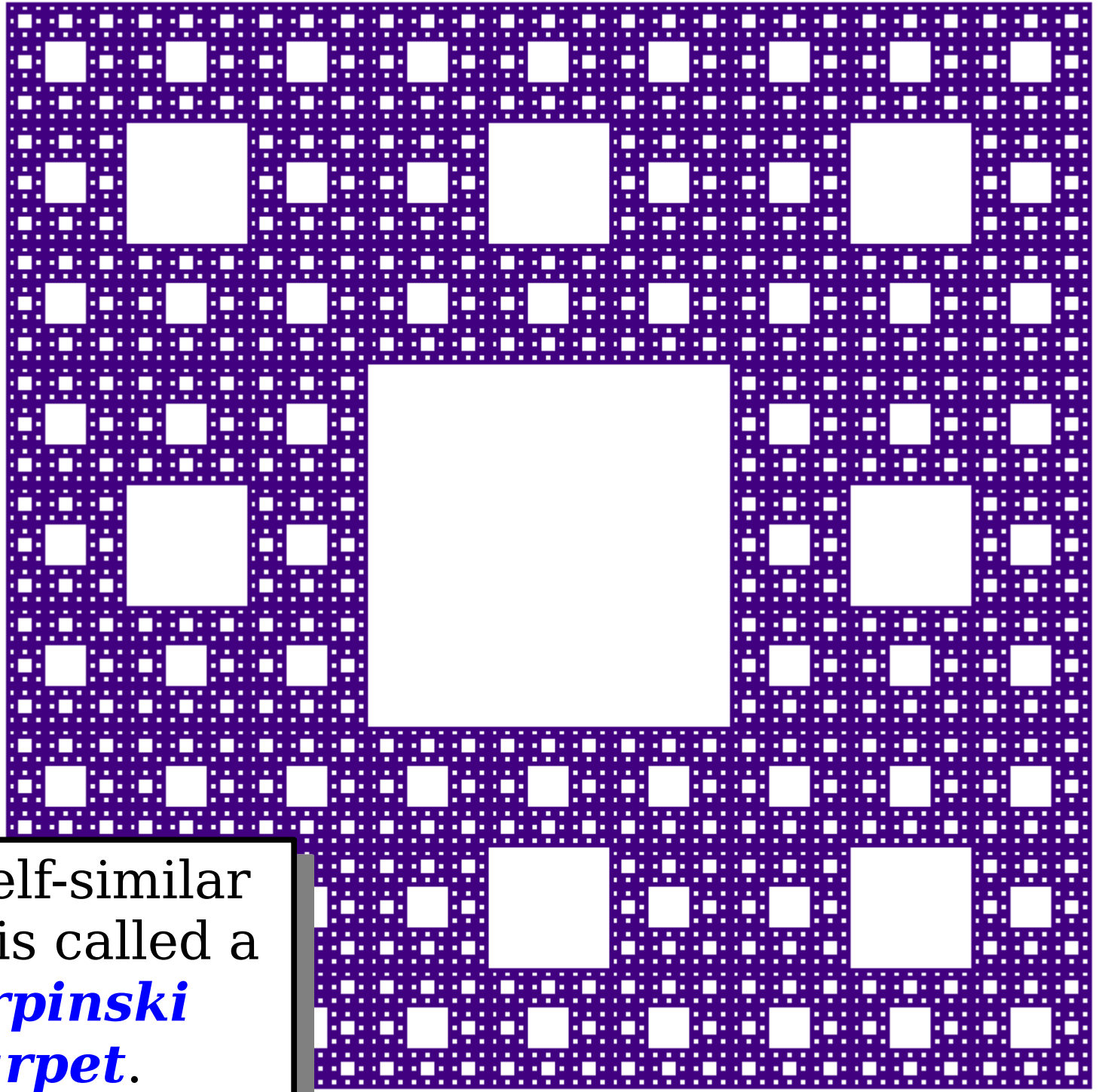
Recap from Last Time

List all ***subsets*** of {1, 2, 3}

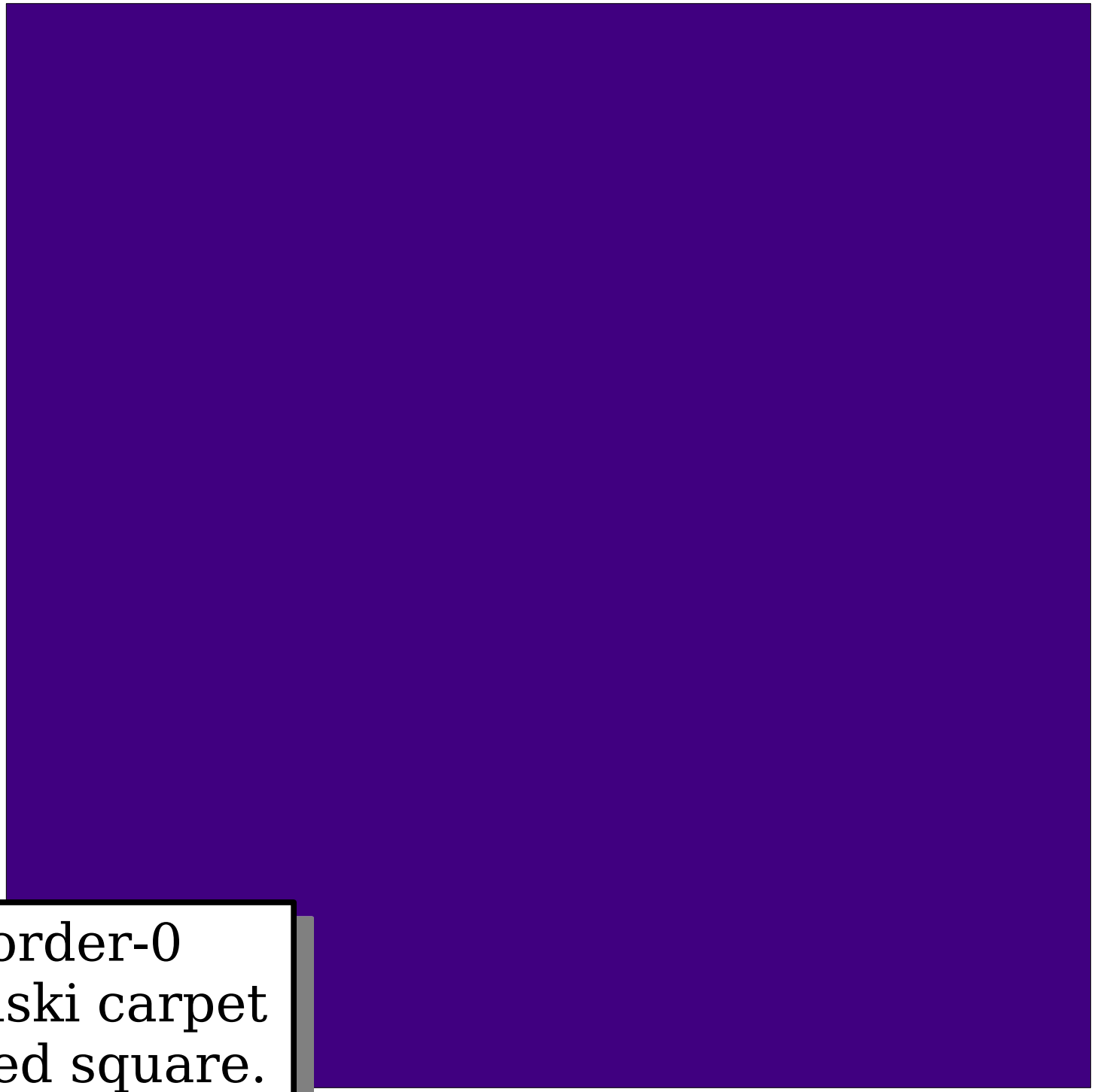


New Stuff!

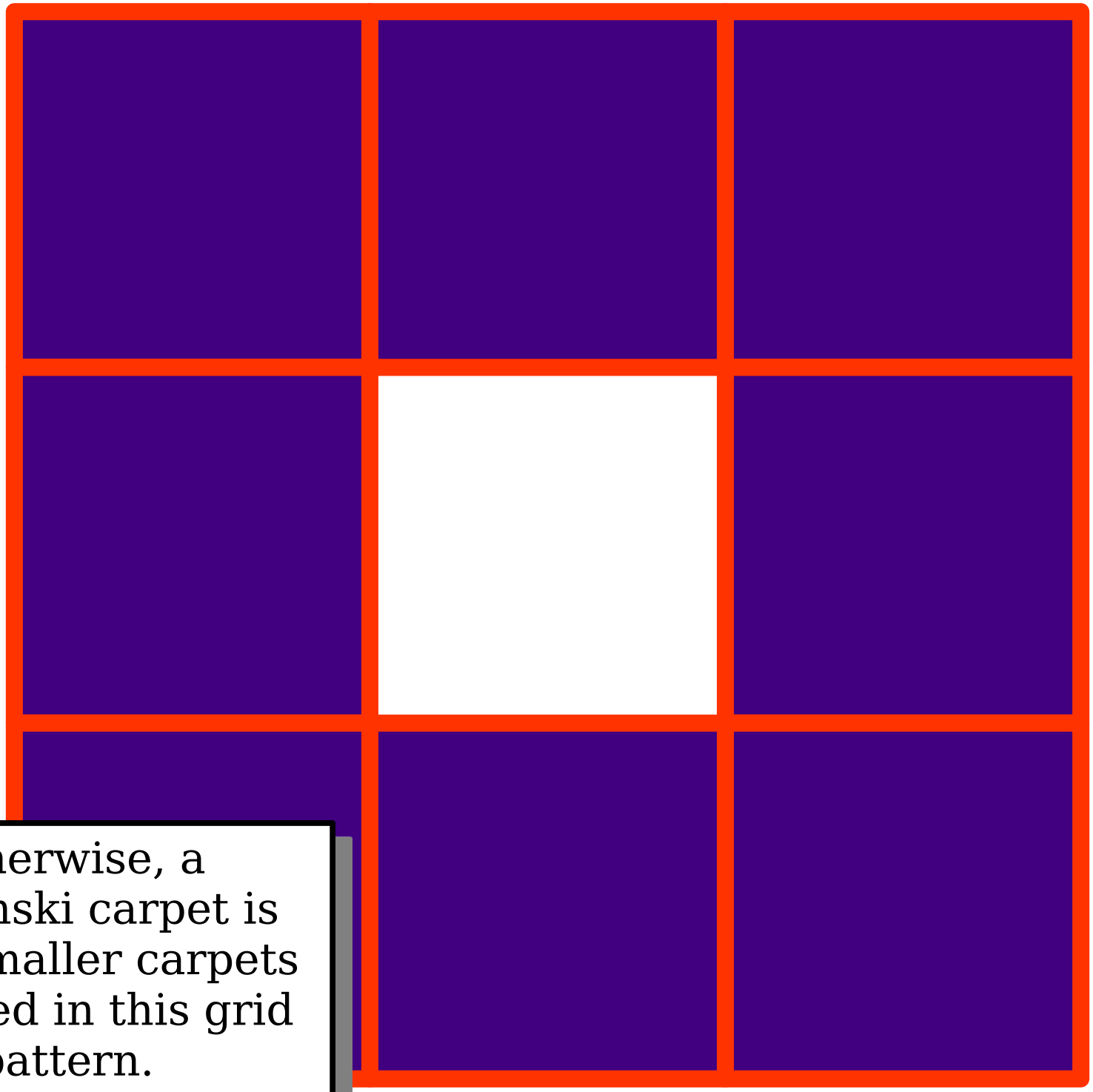
More On Self-Similarity



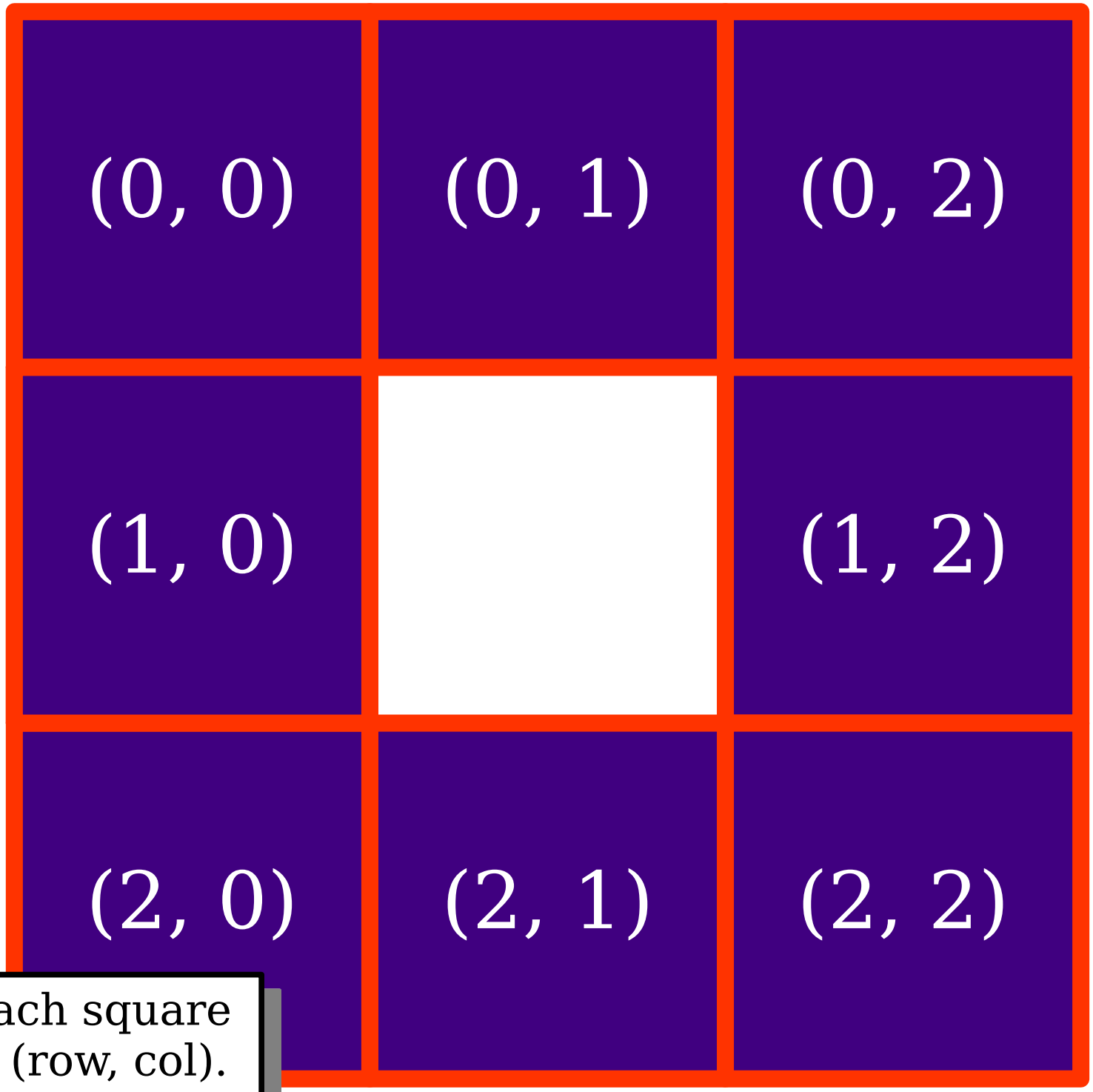
This self-similar shape is called a ***Sierpinski carpet***.

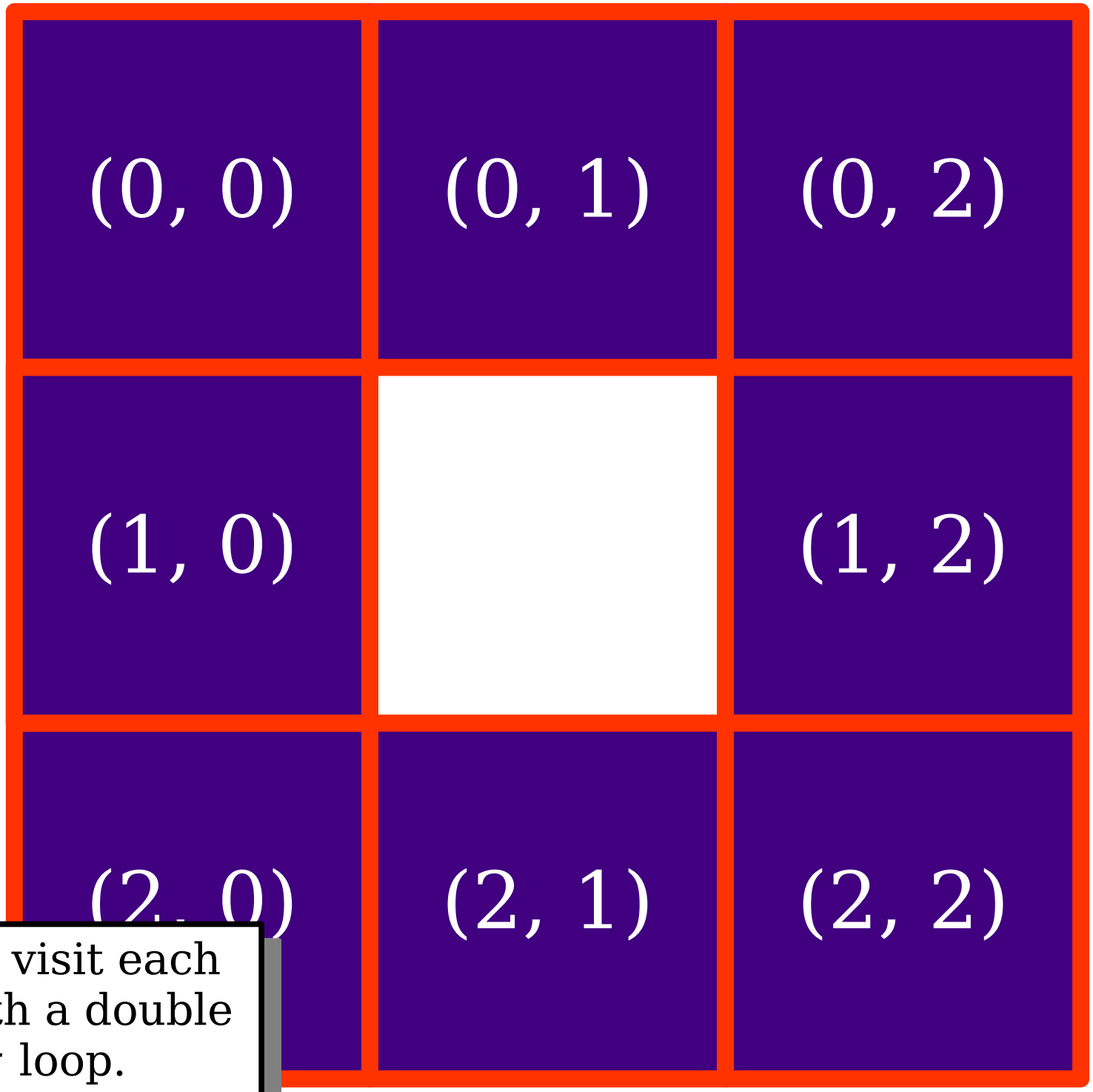


An order-0
Sierpinski carpet
is a filled square.



Otherwise, a Sierpinski carpet is eight smaller carpets arranged in this grid pattern.

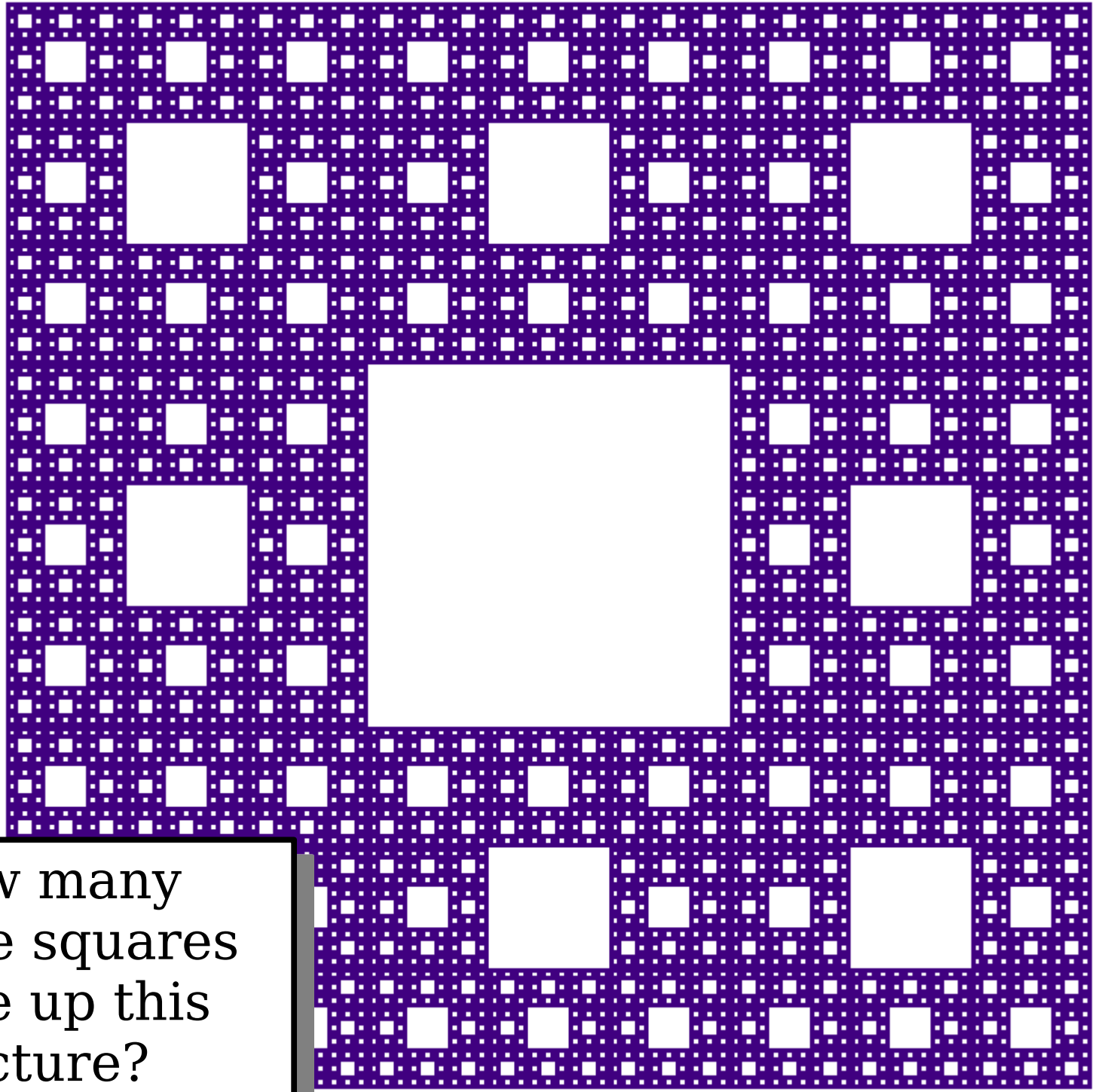

(0, 0)
(0, 1)
(0, 2)
(1, 0)
(1, 2)
(2, 0)
(2, 1)
(2, 2)
Label each square with its (row, col).



We can visit each spot with a double `for` loop.

Iteration + Recursion

- It’s completely reasonable to mix iteration and recursion in the same function.
- Here, we’re firing off eight recursive calls, and the easiest way to do that is with a double `for` loop.
- Recursion doesn’t mean “the absence of iteration.” It just means “solving a problem by solving smaller copies of that same problem.”



How many purple squares make up this picture?

Time-Out for Announcements!

Assignment 3

- Assignment 2 was due today at 1PM.
  - You can use late days to extend the deadline by 24 or 48 hours. Remember that you only get four late days to use over the quarter.
- Assignment 3 (***Recursion!***) goes out today. It's due next Friday at 1:00PM.
  - Play around with recursion and recursive problem-solving!
- ***This assignment may be completed in pairs***. Some reminders:
  - You are not required to work in a pair. It's totally fine to work independently.
  - If you do work in a pair, you must work with someone else in your discussion section.
  - ***Work together, not separately***. Doing only half the assignment teaches you less than half the concepts. Working collaboratively and interactively with your partner will improve your learning outcomes.

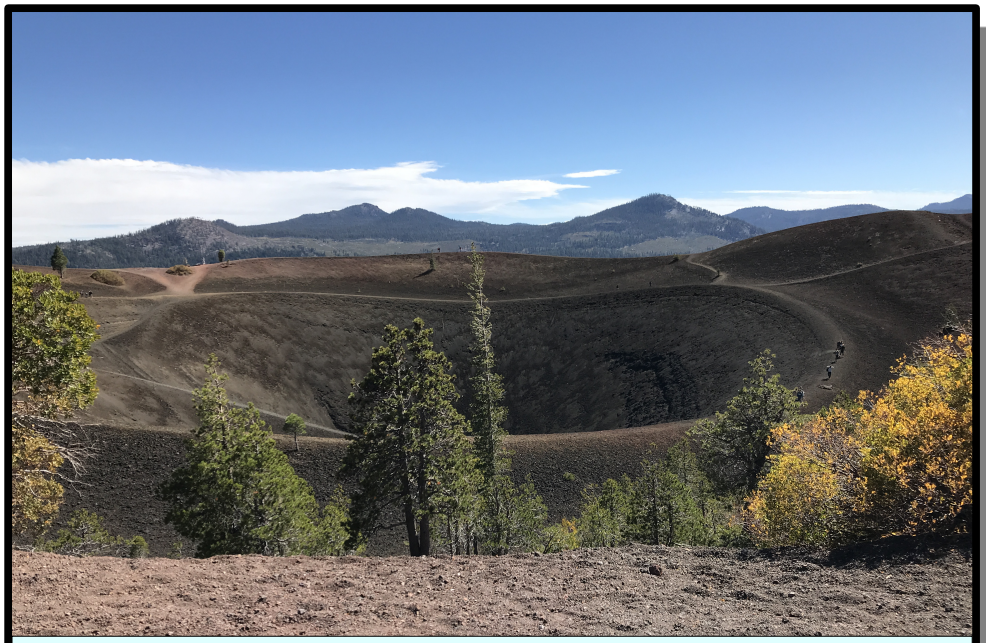
Recursive Drawing Contest

- Our (optional, just for fun) Recursive Drawing contest ends on Monday at 1PM.
- If you're interested in participating, visit ***http://recursivedrawing.com/***, draw something, and post it to EdStem.
- We're very impressed with the submissions you've made so far! If you haven't yet done so, go check them out.

(The Curtain Rises on Act II)

Enumerating Permutations

A ***permutation*** is a rearrangement of the elements of a sequence.



Lassen Volcanic National Park

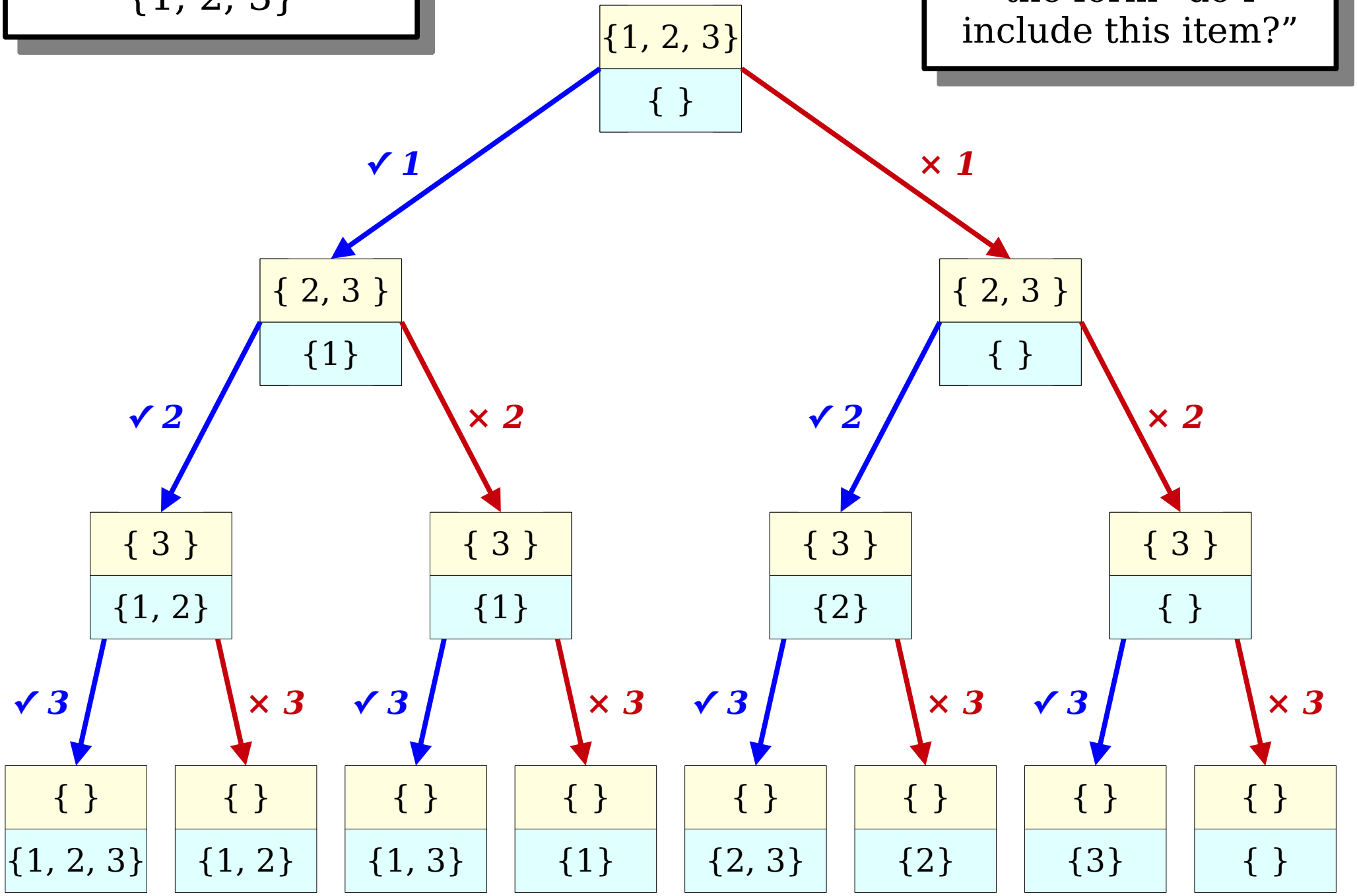
Yosemite National Park

Joshua Tree National Park

Lava Beds National Monument

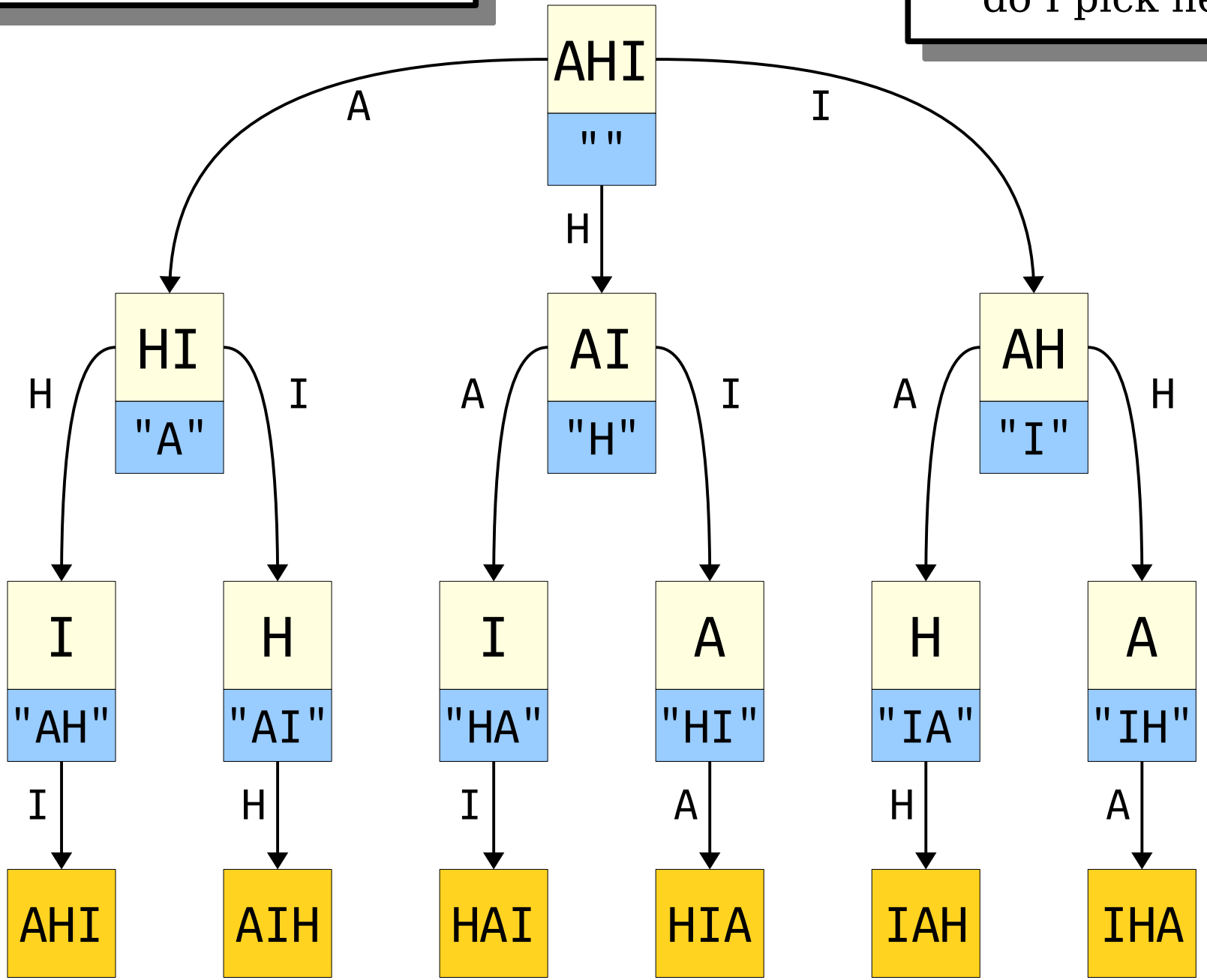
List all ***subsets*** of {1, 2, 3}

Each decision is of the form “do I include this item?”



List all ***permutations*** of {A, H, I}

Each decision is of the form “which item do I pick next?”

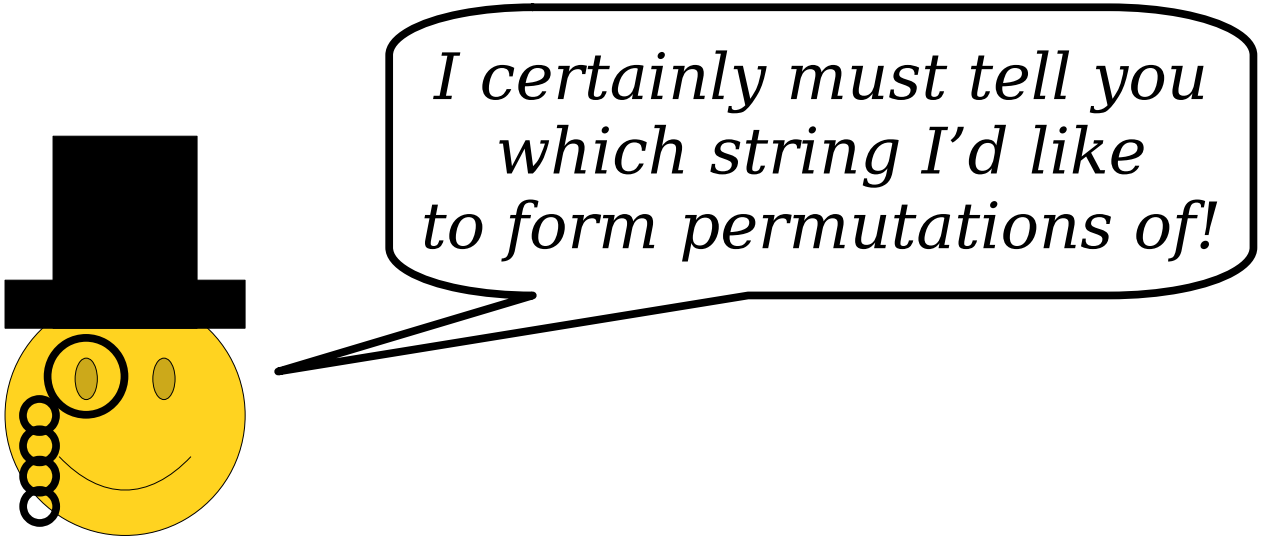


A Question of Parameters

```
listPermutationsOf("AHI", "");
```

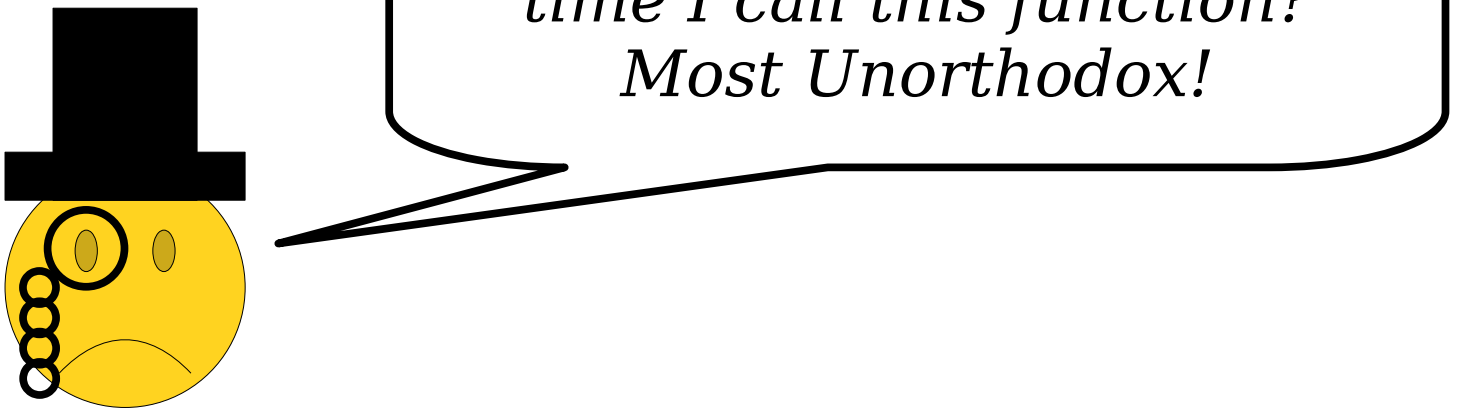
```
listPermutationsOf("AHI", "");
```

```
listPermutationsOf("AHI", "");
```



```
listPermutationsOf("AHI", "");
```

```
listPermutationsOf("AHI", "");
```

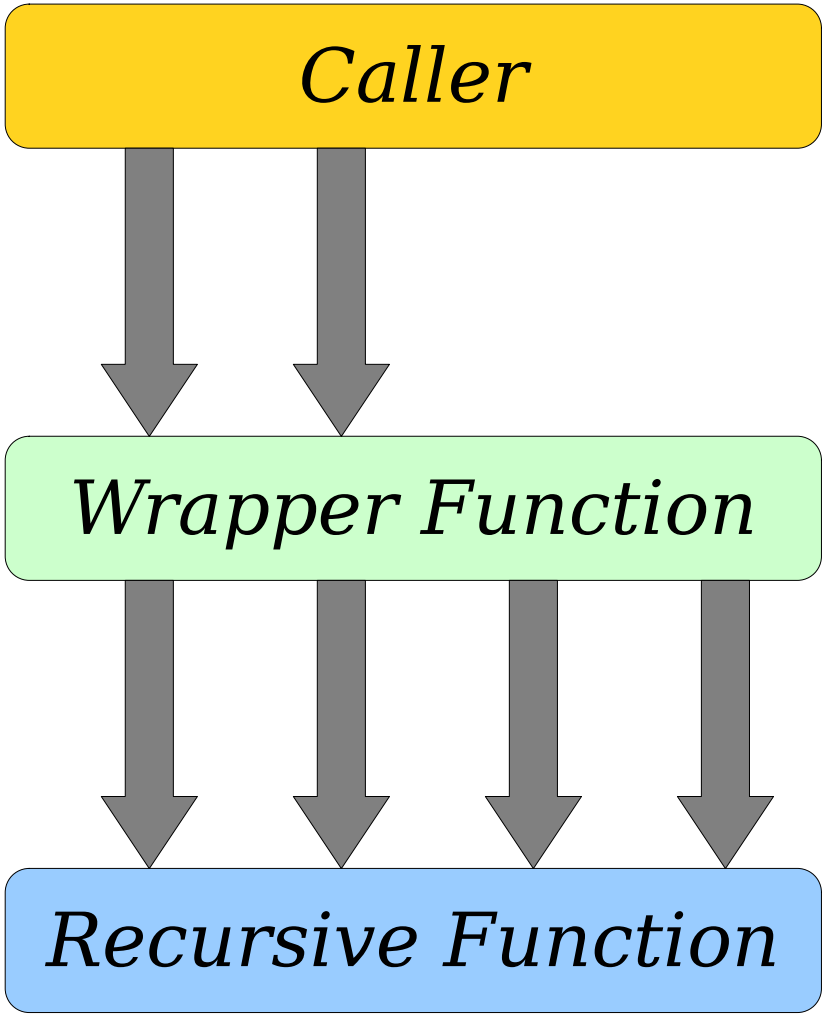


```
listPermutationsOf("AHI");
```

```
listPermutationsOf("AHI");
```

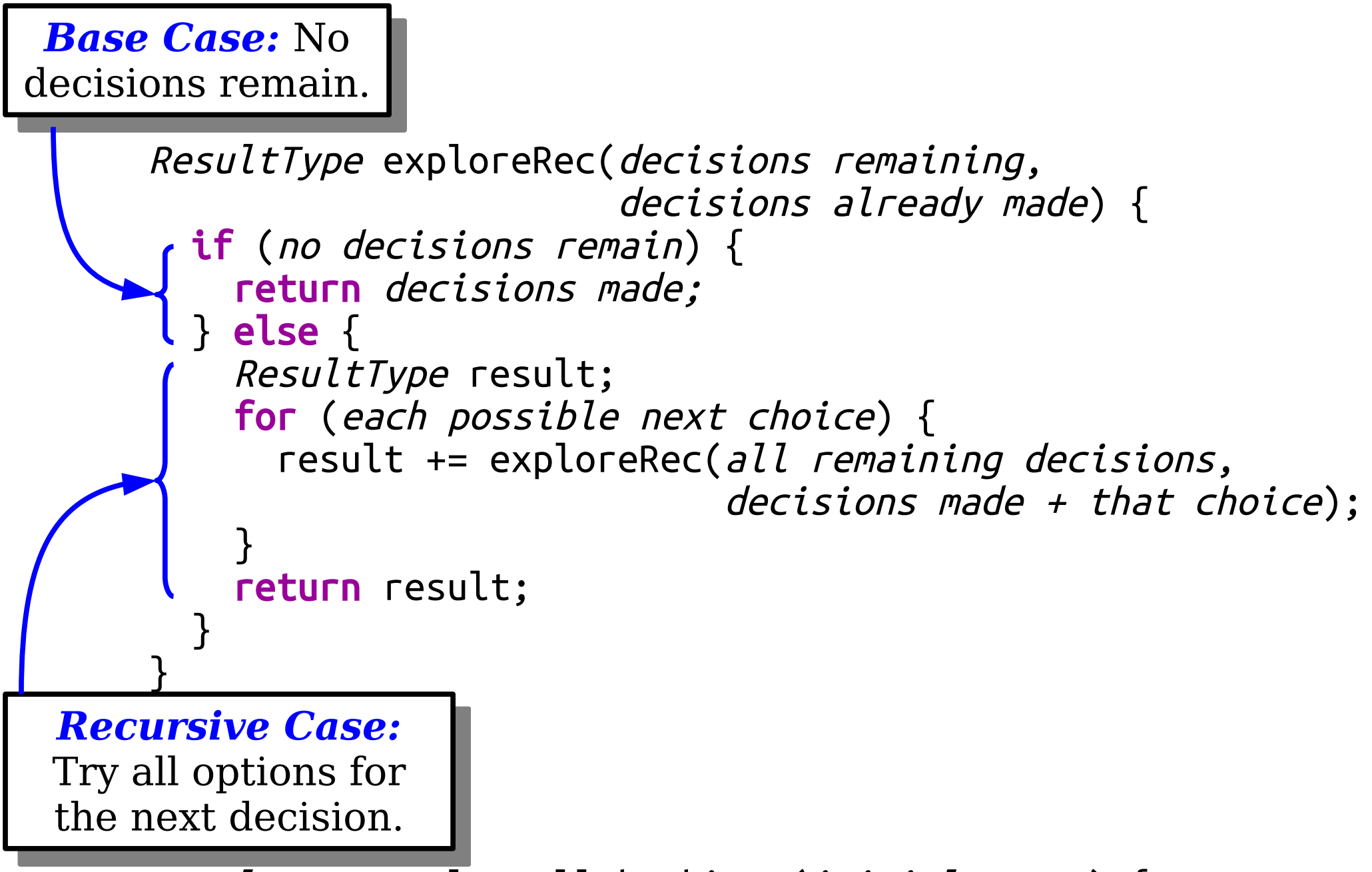
Wrapper Functions

- Some recursive functions need extra arguments as part of an implementation detail.
  - In our case, the string of letters ordered so far is not something we want to expose.
- A ***wrapper function*** is a function that does some initial prep work, then fires off a recursive call with the right arguments.



Storing Permutations

```
Set<string> permutationsOf(const string& str);
```


Base Case: No decisions remain.
ResultType exploreRec(decisions remaining,
decisions already made) {
if (no decisions remain) {
return decisions made;
} else {
ResultType result;
for (each possible next choice) {
result += exploreRec(all remaining decisions,
decisions made + that choice);
}
return result;
}
}
Recursive Case: Try all options for the next decision.
ResultType exploreAllTheThings(initial state) {
return exploreRec(initial state, no decisions made);
}

Summary for Today

- Recursion and iteration aren’t mutually exclusive and are frequently combined.
- We can enumerate subsets using a decision tree of “do I pick this?” We can enumerate permutations using a decision tree of “what do I pick next?”
- Recursive functions can both print all objects of some type and return all objects of some type.

Your Action Items

- ***Read Chapter 8***
  - There are so many goodies there, and it's a great way to complement what we're discussing here.
- ***Work on Assignment 3***
  - Aim to complete the Towers of Hanoi exploration and Human Pyramids by Monday.

Next Time

- ***Enumerating Combinations***
  - Can you build the Dream Team?
- ***Recursive Backtracking***
  - Finding a needle in a haystack.
- ***The Great Shrinkable Word Problem***
  - A fun language exercise with a cute backstory.